ARMY RESEARCH LABORATORY

Tactical Airspace Integration System Situation Awareness Integration Into the Cockpit: Phase II

by Michael Sage Jessee and Anthony Morris

ARL-TR-6371 **March 2013**

prepared by

U.S. Army Research Laboratory
Human Research and Engineering Directorate (AMCOM Field Element)
Bldg 5400, Room C236
Redstone Arsenal, AL 35898-7290

for

Product Manager, Air Traffic Control
Redstone Arsenal, AL 35898-7290

NOTICES

Disclaimers

Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5425

ARL-TR-6371 **March 2013**

Tactical Airspace Integration System Situation Awareness Integration Into the Cockpit: Phase II

Michael Sage Jessee and Anthony Morris
Human Research and Engineering Directorate, ARL

prepared by

U.S. Army Research Laboratory
Human Research and Engineering Directorate (AMCOM Field Element)
Bldg 5400, Room C236
Redstone Arsenal, AL 35898-7290

for

Product Manager, Air Traffic Control
Redstone Arsenal, AL 35898-7290

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*
March 2013

2. REPORT TYPE
Final

3. DATES COVERED (From - To)
January 2010–June 2010

4. TITLE AND SUBTITLE
Tactical Airspace Integration System Situation Awareness Integration Into the Cockpit Phase II

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Michael Sage Jessee and Anthony Morris

5d. PROJECT NUMBER
622716H70

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
Human Research and Engineering Directorate (AMCOM Field Element)
Bldg 5400, Room C236
Redstone Arsenal, AL 35898-7290

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-TR-6371

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Phase II of the Tactical Airspace Integration System (TAIS) Situation Awareness (SA) integration into the cockpit Crew Station Working Group was conducted 19–20 January 2010 in support of the Product Manager, Air Traffic Control. Four experienced U.S. Army rotary wing pilots from a government and contractor consortium were selected as the user group. A series of three vignettes were flown in a generic cockpit representing analog capabilities with the support of an electronic data manager. The pilots were briefed to fly an air movement of troops from the pickup zone to the landing zone and return to the assembly area. Throughout the missions, dynamic airspace events were introduced into the cockpit. Results indicated that with the integration of information pertaining to dynamic airspace updates, the overall aircrew (particularly the copilot) experienced a reduction in workload, a decrease in visual workload, and an increase in SA. Consequently, these data indicated that, within increasingly congested airspace, integrating dynamic airspace information into the cockpit should be taken as a minimal effort to reduce the risk of fratricide and controlled flight into terrain.

15. SUBJECT TERMS
dynamic airspace updates, mental workload, situation awareness, control panel interface, Bedford workload rating

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Michael Sage Jessee
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (*Include area code*)
Unclassified	Unclassified	Unclassified	UU	56	256-842-8830

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

List of Tables

Executive Summary

Phase II of the tactical airspace integration system (TAIS) situation awareness (SA) integration into the cockpit crew station working group (CSWG) was conducted 19–20 January 2010 in support of the product manager, air traffic control (PM-ATC). The purpose of the CSWG was to allow pilots (users), designers, human factors engineers, and representatives of PM-ATC to evaluate and participate in the CSWG. Results indicated that with the integration of information pertaining to dynamic airspace updates, the overall air crew (particularly the copilot) experienced a reduction in workload, a decrease in visual workload, and an increase in SA. Consequently, these data indicated that, within increasingly congested airspace, integrating dynamic airspace information into the cockpit should be minimized to reduce the risk of fratricide and controlled flight into terrain. Four experienced U.S. Army rotary-wing pilots from a government and contractor consortium were selected as the user group. A series of three vignettes were flown in a generic cockpit representing analog capabilities with the support of an electronic data manager (EDM). The pilots were briefed to fly an air movement of troops from the pickup zone to the landing zone and return to the assembly area. Throughout the mission, dynamic airspace events were introduced into the cockpit. The first vignette represented current capabilities, in which only preloaded flight information was presented on the EDM while dynamic airspace events were communicated via radio. In the second vignette, dynamic airspace information was automatically transmitted to the EDM from the TAIS. In the third vignette, dynamic airspace information from TAIS was presented with an auditory annunciation.

INTENTIONALLY LEFT BLANK.

1. Introduction

1.1 Background and Purpose

The tactical airspace integration system (TAIS) situational awareness (SA) integration into the cockpit effort consists of a series of Crew Station Working Group (CSWG) meetings that evaluate the effects of dynamically integrating TAIS symbology into the cockpit. This will provide pilots with near-real-time airspace information in an increasingly dynamic and often congested airspace environment. This specific study aimed to measure air crew workload (WLD) and SA variations resulting from the introduction of TAIS symbology into currently fielded analog aircraft in which electronic data managers (EDMs) are used for navigation.

The U.S. Army Research Laboratory (ARL) Human Research and Engineering Directorate (HRED) conducted the assessment of WLD and SA that pilots experienced while flying simulated missions. The assessment was conducted to determine the effects of integrating dynamic airspace symbology from TAIS automatically into the copilot's electronic data manager (EDM) as compared to similar information verbally relayed to the pilots by an air traffic controller (ATC). The cognitive decision aiding system had to provide a workload environment for the crew with a Bedford workload rating scale (BWRS) mean score not exceeding 6.0.

1.2 Simulation Description

A simulated analog cockpit was used to address the near-term potential goal of integrating TAIS symbology into cockpits in which EDMs are commonly used. The EDM was linked to a TAIS box via Winzel, which allowed dynamic airspace control measures (ACMs) and air tracks to be transmitted automatically to the EDM. Flight scenarios were flown in the battlefield highly immersive virtual environment (BHIVE) located in the System Simulation Development Directorate (SSDD) 19–20 February 2010. There were two multifunctional displays (MFDs) for each pilot but only one was enabled, which presented information similar to analog cockpits for each pilot. For navigation information, the copilot relied primarily on the outside the window (OTW) scene and the digital map presented on the EDM.

1.3 Assessment Overview

The assessment consisted of operational missions conducted by experienced pilots in the BHIVE. Simulation training was not required because all pilots were experienced with the particular cockpit and simulation environment. Before entering the simulation, pilots were provided a mission brief and their flight plan. Prior to the beginning of data collection, the copilot was fitted with the head and eye tracker, which was then calibrated. The mission scenario was a standard air escort mission developed by subject matter experts (SMEs) within

SSDD in accordance with established aircraft tactics, techniques, and procedures. The pilots flew the same mission for vignette 1 (V1), vignette 2 (V2), and vignette 3 (V3), but different capabilities were introduced during each vignette.

Each mission lasted roughly 40 minutes, after which pilots were sequestered to a calm environment where air crew responses were captured with surveys and the after action review (AAR) process.

2. Method

2.1 Data Collection

Pilot workload, SA, visual dwell times, audio-video recordings, flight performance, and open-ended survey data were collected and analyzed. These data were assessed to determine: (1) the SA effect of bringing TAIS symbology into the cockpit in real time, (2) the workload implications for accessing dynamic airspace update (DAU) information with and without TAIS SA integration support, (3) flight performance of the pilot crew in terms of efficient deviations from restricted operating zones (ROZs) that obstruct the flight path, and (4) pilot/user community attitudes and feedback regarding the capability.

The BWRS, SA reporting technique (SART), and open-ended questionnaires were developed in accordance with published guidelines for proper format and content (O'Brien and Charlton, 1996). After each flight scenario, the pilot and copilot completed the BWS, SART, and an open-ended questionnaire. For the purpose of this study, each questionnaire packet was modified for relevant pilot and copilot tasks related to the use of the EDM with and without TAIS SA integration. Additional data were collected from the pilots and SMEs via real-time observation of the flight scenarios, postmission discussions, and AARs.

2.2 Evaluation Design

The nature of this evaluation focused on operational realism, which was most appropriate for fulfilling customer requirements, rather than internal validity. However, multiple variables were controlled to maximize the validity and ensure that the results can be generalized. To evaluate the effects of TAIS SA being transmitted to the EDM, pilot and crew performance was captured under three conditions: (1) current capability, (2) TAIS SA integration into the cockpit, and (3) TAIS SA integration into the cockpit with annunciations (alerts that a dynamic event has been transmitted to the EDM). Pilot experience (expert level), flight scenario, training, lighting conditions, and seat position were held constant to control for potential confounds. The right seat was designated as the pilot and left seat as the copilot, with the EDM user always in the left seat. Each crewmember flew at least one of three flight scenarios in the copilot seat to collect EDM user data from all pilot perspectives.

2.3 Flight Vignettes

Three different flight vignettes were flown by each pilot crew, representing three variations of SA information transmission strategies. Each crew remained constant throughout the vignettes. Ten DAU items were introduced into the cockpit for each vignette (see table 1). The purpose was to evaluate the effects of transmitting DAU to the pilot crew in three different ways. The first vignette simulated the current capability of transmitting DAUs into the cockpit. In this condition, pilots loaded the aircraft with their aviation mission planning system (AMPS) card, consisting of three preloaded items represented by the gray shaded boxes in table 1. The remaining seven items were introduced to the pilots after they took off and reached predefined locations in which each DAU was presented. The flight route is shown in figure 1.

Table 1. Air control measure items.

1.	Control zone at Pickup Zone Irwin
2.	ROZ “A1” displayed between SP1 and ACP1
3.	Raven unmanned aerial vehicle (UAV) air track after ACP2
4.	ROZ “C3” displayed between ACP4 and ACP5
5.	ROZ “F5” at Landing Zone Devil
6.	Air corridor “Blue”
7.	Predator air track in air corridor “Blue”
8.	Air corridor “Chevy”
9.	ROZ “A3” at “Dog Leg” on air corridor “Chevy”
10.	Flight of two (2) AH-64 air track in air corridor “Chevy”

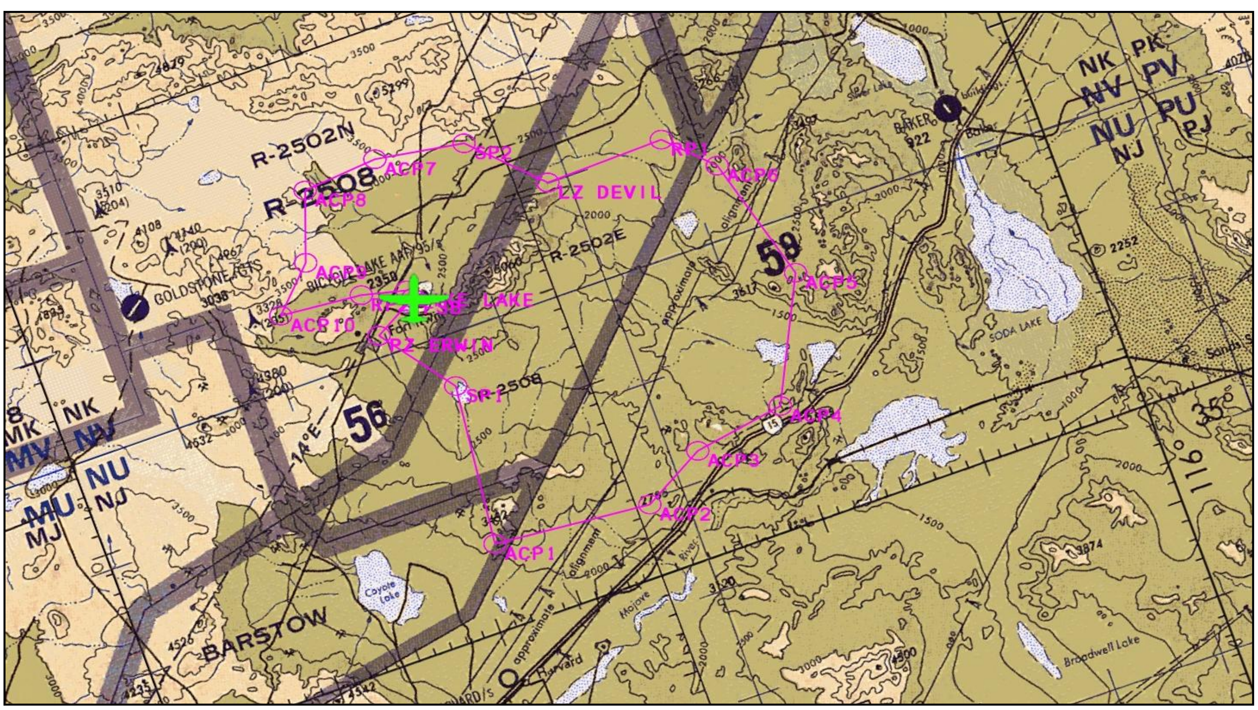


Figure 1. Preplanned flight route.

During the first vignette, each DAU was transmitted via voice communication from the battle master station to the simulated cockpit. Here, pilots had to write down altitude and latitude/longitude coordinates communicated by the ATC. After that, the copilot compared the coordinates to coordinate locations on the EDM digital map to find physical landmarks that he/she could then reference, and then recommended a plan of action to the pilot.

The second vignette consisted of the same ACMs and flight route. However, when the DAUs were introduced into the flight scenario, they were transmitted directly onto the EDM digital map, allowing the copilot to acquire the spatial location of potentially threatening airspace objects by simply viewing their location on the digital map. Current capability would dictate that this information, if received, would be "mentally calculated" and visualized by the copilot to locate the ACM on the digital map based on coordinates received by the ATC.

The third vignette consisted of the same ACM items and flight route, but introduced verbal annunciations from the ATC when the DAU was introduced. The purpose of this was to evaluate how an annunciation of new ACM information affected WLD and SA. The expectation was that a verbal annunciation would alleviate visual resources used to monitor the airspace instead of the digital map display, facilitating a more beneficial allocation of attention.

2.4 Participants and Demographics

Four U.S. Army rotary-wing aviators participated in this event. The demographics questionnaire consisted of basic information on each pilot. Flying experience for each pilot across major aircraft platforms is presented in table 2.

Table 2. Pilot flying experience.

Pilot PIN	Qualified Platform	IP Hours	PI Hours	PIC Hours	NVD Hours
001	OH-58A	—	200	—	—
	OH-58D	—	450	—	—
	UH-1	—	150	—	—
	UH-60	1500	750	2500	750
002	UH-1	—	228	100	50
	CH-47	2500	750	750	1700
003	OH-58A	1000	500	500	600
	UH-1	—	125	—	50
	UH-60	1500	1000	1500	1000
004	UH-1	1000	200	1500	150
	CH-47	800	100	1500	150
Totals	OH-58A	1000	700	500	600
	OH-58D	—	450	—	—
	UH-1	1000	703	1600	250
	UH-60	3000	1750	4000	1750
	CH-47	3300	850	2250	1850
Overall	—	8300	4453	8350	4450
Total flight time across all platforms = 25,553					

Note: PIN = personal identification number; IP = instructor pilot; PI = pilot; PIC = pilot in command; and NVD = night vision device.

2.5 Assessment of Crew Workload

One accepted definition of mental workload (MWL), as proposed by Young and Stanton (2001), suggests that the MWL of a task represents the level of attentional resources required to meet both objective and subjective performance criteria and is mediated by task demand, external support, and past experience. Pilot workload is a particularly important construct because overall mission accomplishments are directly related to the resources required to meet pilot objectives. Excessively high workload results in task shedding, poor decisionmaking, and decreased performance. One goal of the human factors engineer is to manipulate external support so operators are able to accomplish tasks while reducing the amount of resources required to accomplish their objectives. As such, the currently implemented test design controlled for task demand (held tasks constant across test conditions) and past experience (only used experienced pilots) while changing external support (EDM with TAIS symbology vs. no TAIS symbology).

2.5.1 Bedford Workload Rating Scale (BWRS)

Immediately after each mission, pilots completed the BWRS, which assesses subjective pilot workload via a unidimensional decision tree (appendix A) for tasks predicted to have the most impact on air crew workload during the mission.

The BWRS has been used extensively by the military, civil, and commercial aviation communities for pilot workload estimations (Roscoe and Ellis, 1990). Essentially, it measures spare capacity and requires the participant to answer a series of discrete questions related to spare capacity to reach a specific workload rating. Spare workload capacity is an important resource for pilots because they are often required to perform several tasks concurrently; for example, perform navigation tasks, communicate via multiple radios, aviate the aircraft, and monitor the system.

2.5.2 Visual Workload

Visual workload refers to the amount of time the pilots' visual attention is diverted from the OTW scene to the instrument cluster. Essentially, this means that as the pilots spend more time focusing their visual attention inside the cockpit, the higher the visual workload. To quantify this, a head and eye tracker system was implemented to calculate overall dwell times for pilots' gaze behavior. This data was collected to determine how the addition of the TAIS symbology that was integrated into the EDM affected how visual attention was distributed in the cockpit. Specifically, the data would be used to determine if TAIS symbology allowed copilots to spend more time focusing their attention OTW.

2.6 Assessment of Crew Situational Awareness

SA can be defined as the pilot's mental model of the current state of the flight and mission environment. A more formal definition is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988). The importance of SA lies in its correlation with performance. Pilots that report higher SA also demonstrate better decisionmaking and overall performance. For the current study, increases in SA should improve navigation around unexpected obstacles.

2.6.1 Situation Awareness Rating Technique (SART)

The SART (appendix B) is a multidimensional rating scale that captures three components of SA: (1) demand of attentional resources, (2) supply of attentional resources, and (3) understanding. Taylor (1990) developed it specifically for air crew systems and suggested that SA depends on the pilot's understanding (U) (e.g., quality of information they receive) and the difference between the demand (D) on the pilot's resources (e.g., complexity of mission) and the pilot's supply (S) (e.g., ability to concentrate). When D exceeds S, there is a negative effect on U and an overall reduction of SA. The formula $SA = U - (D - S)$ is used to derive the overall SART score. According to Endsley (2000), the SART is one of the most thoroughly tested rating scales for estimating SA.

2.6.2 Battlefield Elements SA Questionnaire

The battlefield elements SA questionnaire (appendix C) is a five-point Likert-type scale that assesses self-reported SA on a series of questions; for example, location of friendly units, location of my aircraft during the mission, and location of other aircraft related to the mission. This questionnaire allows pilots to rate their own level of SA.

2.7 EDM Interface

The EDM is a device currently fielded for improving SA in analog cockpits. The purpose of this capability is to enhance SA and contribute to successful mission performance by transmitting near-real-time TAIS symbology to the EDM to provide important DAUs to the pilots. To assess the effectiveness of the EDM, questionnaires were developed to allow pilots to report at the end of each mission any problems that contributed to high workload and low SA. The EDM questionnaire addressed the integration of near-real-time TAIS symbology and is presented in appendix D.

2.8 Overhead Cockpit Cameras

Two over-the-shoulder cameras were mounted above the left and right seat to record pilot actions. This aided in determining what the pilots were doing during the different phases of the mission. The cameras had a time stamp so that elapsed time could be compared with other data collected.

2.9 Head and Eye Tracker System

Copilot visual gaze and dwell times were collected with a head and eye tracking system from Applied Science Laboratories (ASL). The ASL eye-head package included a Model 501 eye tracker and an Ascension Laserbird head tracker. This system was primarily selected because of its eye-head integration capability, which allowed unrestricted head movement. This technology enabled researchers to collect data that specified point of gaze with respect to stationary objects (MFDs) within the cockpit. The ASL software allowed data collectors to continuously monitor the eye position of the pilots with crosshairs superimposed over live imagery (figure 2). The software also included a built-in analysis tool that facilitated data viewing in a tabular or graphical format.

Figure 2. Eye tracker, pupil/camera monitors, and control panel interface.

2.10 Data Analysis

Pilot responses to the BWRS, SART, and open-ended questionnaires were illustrated using mean and percentage descriptors. Their responses were further analyzed with the Wilcoxon signed rank test (WSRT) to compare the rating between the pilot and copilot and across each previously mentioned test condition to determine if the differences were statistically significant (≤0.05).

Eye tracker data were summarized by calculating the total percentage of fixations that occurred for the different areas of interest (AOIs). Five AOIs were created for the copilot: (1) primary display, (2) OTW, (3) kneeboard and EDM, (4) pilot instrument panel, and (5) other, the latter being eye fixations not focused on a specific AOI.

2.11 Evaluation Limitations

Several limitations must be considered when interpreting the data listed in the results section.

- There was a small sample size of pilots ($N = 4$) that may not be representative of the total population.

- Flight controls were not available to the copilot, as would be the case in a real life situation.
- There was no training for the EDM.
- The same mission scenario was used for each vignette, possibly introducing a learning effect.
- Global positioning system data did not consistently synchronize to the EDM throughout the event.

These limitations are not uncommon when replicating a complex aviation system in a simulator. However, the information the data listed in the results and summary sections of this report should be interpreted in the context of these limitations. Additional data should be collected during future simulations and tests to augment and expand the findings in this report.

3. Results

3.1 Crew Workload – Average Bedford Workload (BWL) Ratings for Flight and Mission Tasks

The overall crew workload (pilot and copilot) rating for all aircraft training manual (ATM) tasks for V1 was 3.5 (scale ranging 1–10). For V2 and V3, the mean overall crew workload rating for all ATM tasks was 2.65 and 2.67, respectively. All average BWL scores can be viewed in table 3. A workload rating between 2 and 3 indicates that pilots typically had "enough workload capacity for all desirable additional tasks," while a rating of 3.5 indicates that pilots had "insufficient workload capacity for easy attention to additional tasks." The difference in workload between V1 and V2 was statistically significant (WSRT, $z = –3.33$, $p < 0.001$). However, the overall workload scores between V2 and V3 were not statistically significant (WSRT, $z = –0.05$, $p = 0.96$).

When making the same comparisons for pilot and copilot data, a similar pattern emerged. Copilot overall workload significantly reduced from V1 to V2 (WSRT, $z = –4.6$, $p < 0.001$), but no significant difference was detected from V2 to V3 (WSRT, $z = –1.05$, $p > 0.05$). However, pilot overall workload significantly increased from V1 to V2 (WSRT, $z = –2.24$, $p < 0.05$), but showed no significant differences between V2 and V3 (WSRT, $z = –1.3$, $p = 0.195$).

When investigating average BWL scores per task across vignettes, the highest three scores should be addressed. During V1, the copilot found it particularly difficult to maintain airspace surveillance (ATM task 1026). An average score of 6 indicates that "the level of effort allows little attention to additional tasks." In addition, the dynamic events that occurred in V1 caused a reduction in spare capacity for the copilot while using the EDM. A score of 5 (navigate EDM pages) indicates that "additional tasks cannot be given the *desired* amount of attention," while reading the symbology and changing the map scales received an average BWL score of 4, indicating "insufficient workload capacity for *easy* attention to additional tasks."

Table 3. Average BWL scores.

ATM Task	Average Pilot Workload Data			Average Copilot Workload Data			Overall Workload Data		
	V1	V2	V3	V1	V2	V3	V1	V2	V3
1026 – Maintain airspace surveillance	2.5	3	2.3	6	3	2.3	4.25	3	2.3
1032 – Perform radio communication procedures	2.5	3	2.3	3.5	1.6	2.3	3	2.3	2.3
1044 – Navigate by pilotage and dead reckoning	2.5	3	2.6	3.5	2.3	2.6	3	2.7	2.6
1054 – Select landing zone/pickup zone/holding area	2.5	3	2.6	3.5	2.3	2.6	3	2.7	2.6
2024 – Perform terrain flight navigation	2.5	3	2.6	3.5	2.6	2.6	3	2.8	2.6
1146 – Perform electronically aided navigation	—	—	—	3.5	2.3	2.6	—	—	—
1260 – Operate digital map	—	—	—	3.5	2.6	2.6	—	—	—
Average across ATM tasks	2.5	3	2.5	3.9	2.4	2.5	3.25	2.7	2.5
EDM Tasks									
Navigate EDM	—	—	—	5	3	3	—	—	—
Read EDM symbology	—	—	—	4	3.3	3.6	—	—	—
Communicate EDM navigation information to the pilot	—	—	—	3.5	2	2.6	—	—	—
Change EDM map scale	—	—	—	4	2	3	—	—	—

3.1.1 Impact of Workload on Aircrew Coordination

During V1, the copilot was required to spend a significant amount of time writing down grid coordinates to map out DAUs that could not be preloaded onto the AMPS data card. Often, the pilot had already flown through the ROZ by the time the copilot was able to coordinate an alternate flight path. During V2 and V3, verbal air crew coordination increased significantly because the copilot was able to instantly observe the DAU in reference to the preplanned flight and coordinate an alternate path more efficiently. This pattern is reflected in the following description of visual gaze data.

3.1.2 Visual Workload

Data from the head and eye tracker system were categorized into the five AOIs in figure 3. The OTW AOI includes all gaze data from copilots viewing the environmental scene. The AOI-labeled pilot instruments simply include the center and pilot instrument console. The heads-down data include both the EDM and notepad, while primary display includes the instrument panel directly in front of the copilot. The AOI-labeled “other” includes all data that did not fall within one of the previously mentioned AOIs.

Figure 3. AOIs used to calculate visual workload.

Figure 4 shows the average percentage of time that the copilot was visually focused in each AOI during V1. As can be seen, the copilot spent nearly 79% of the time focusing on the EDM and notepad used to write down coordinates of dynamic airspace events. Since both of these AOIs were able to move freely, the eye tracking system does not allow reliable resolution of the exact percentage differences between the notepad and EDM. However, based on a review of the video, it was generally observed that the copilot spends a significant and unsafe portion of time writing grid coordinates for dynamic airspace events. Furthermore, regardless of the area of fixation (EDM or notepad), both AOIs require deep heads-down engagement.

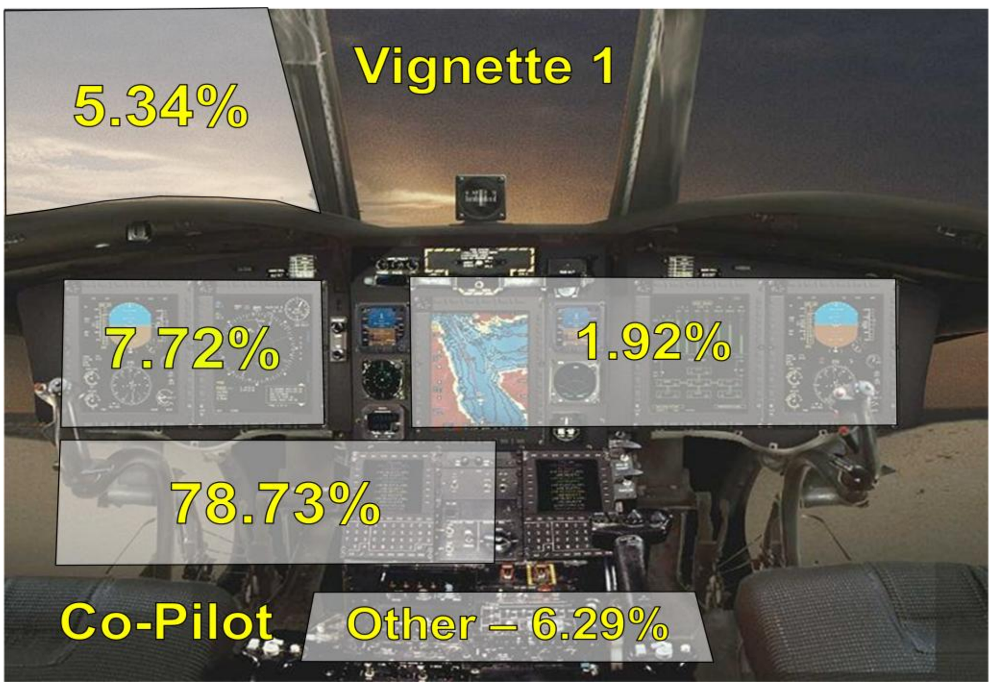


Figure 4. Vignette 1 gaze percentages.

Figure 5 shows the percentage of time that the copilot was visually focused in each AOI during V2. A fivefold increase in heads-up time resulted from the transmission of dynamic airspace information directly to the EDM. Although 55.85% heads-down time is still a significant portion of time looking deep within the cockpit, it is important to note that these vignettes were designed to represent heavy navigational task loading on the copilot. This was done to create a realistic environment representative of the increasingly congested and dynamic airspace.

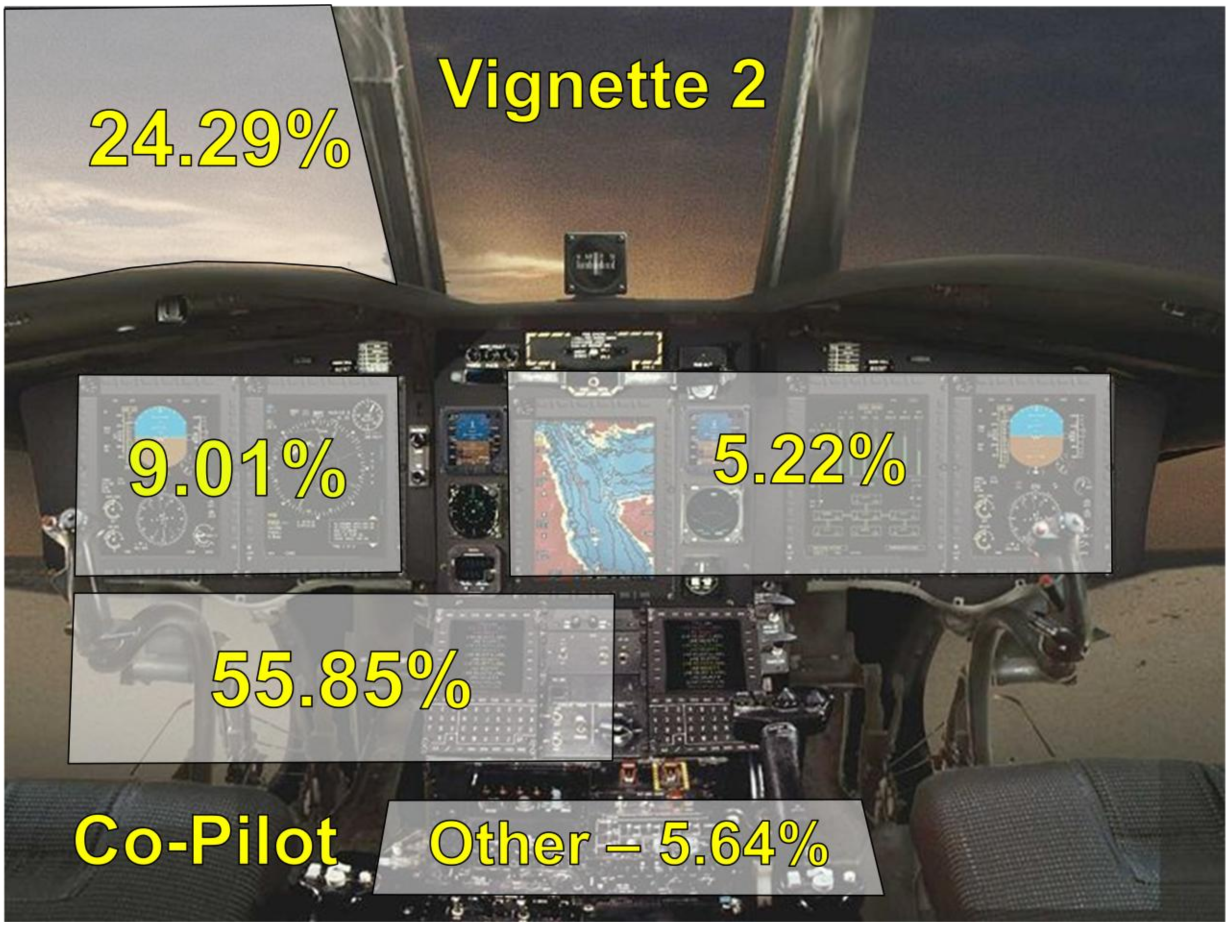


Figure 5. Vignette 2 gaze percentages.

Figure 6 shows the percentage of time that the copilot was visually focused in each AOI during V3. This data suggests that there is no difference in visual workload between V2 and V3. However, the users reported that annunciations of dynamic events were helpful indicators that increased SA. During this test event, eye tracker data were not sensitive to annunciations of dynamic events present in V3.

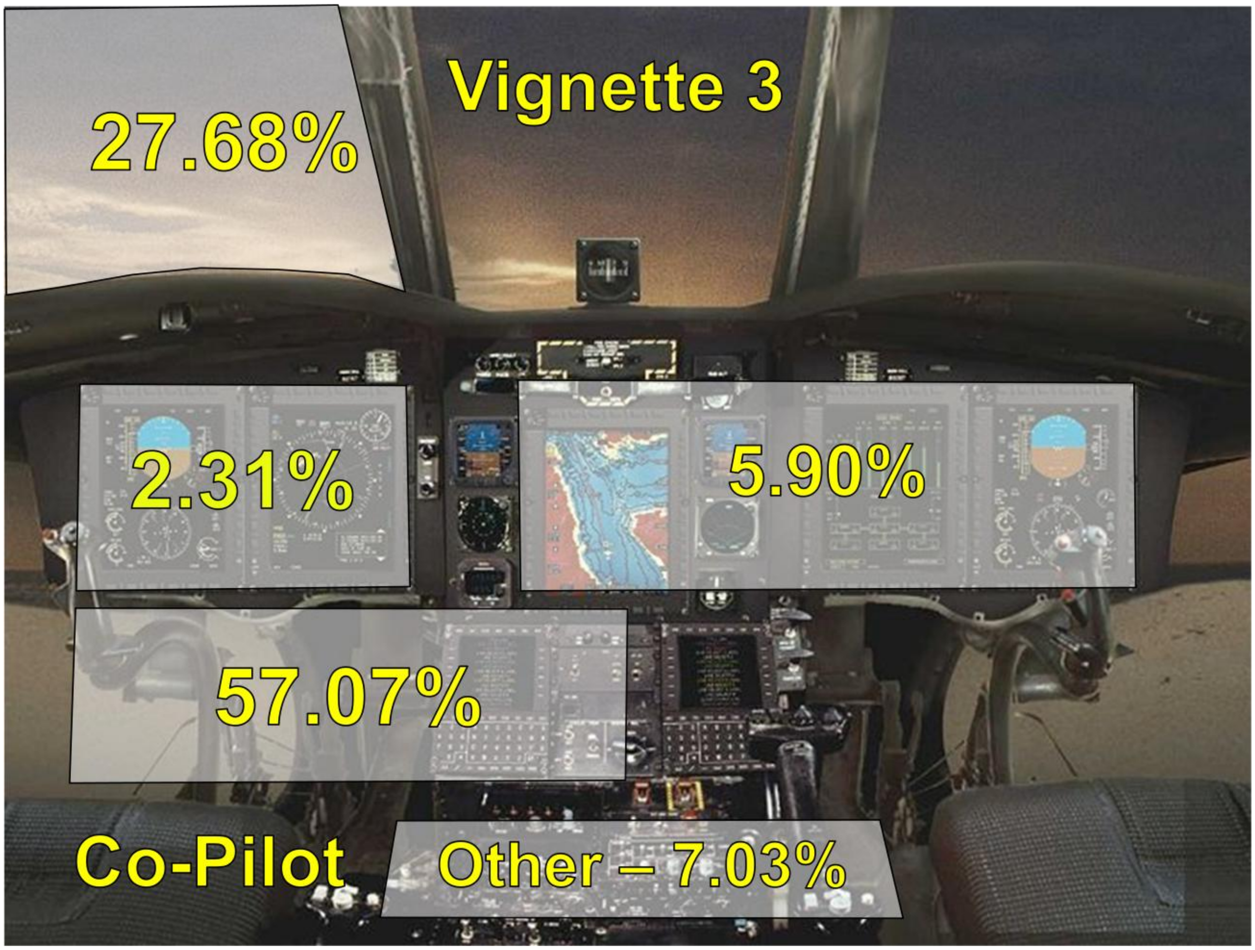


Figure 6. Vignette 3 gaze percentages.

3.2 Crew Situation Awareness

Pilot and copilot SART scores (table 4) are inconclusive because of limited statistical power. Although the pilot's SART scores remained relatively constant across vignettes, the copilot's SART scores demonstrate a trend toward improved SA.

Table 4. Overall SART scores across vignettes.

SART Scores		Vignette 1	Vignette 2	Vignette 3
Pilot	Participant 1	27	33	16
	Participant 2	16	12	16
	Participant 3	22	16	28
Average Pilot SART Scores		21.7	20.3	20
Copilot	Participant 1	12	23	22
	Participant 2	No response	22	16
	Participant 3	NA	12	28
Average Copilot SART Scores		12	19	22

Note: NA = not applicable.

Data from the battlefield elements SA questionnaire, illustrated in table 5, indicate that SA significantly increased from V1 to V2 but not from V2 to V3. As would be expected, there were also significant statistical differences between V1 and V3. These comparisons were conducted for the overall crew (pilot and copilot data combined) and per the pilot and copilot data. The same trend was observed for all three comparison sets; for example, pilot data across all vignettes, copilot data across all vignettes, and overall crew data across all vignettes. Table 5 illustrates the statistical results of each comparison.

Table 5. Situation awareness comparisons for crews, pilots, and vignettes.

Comparison	Wilcoxon Signed Rank Test Results
Crew V1 vs. Crew V2	WSRT, z = -2.328, p = 0.02[a]
Crew V2 vs. Crew V3	WSRT, z = -.237, p > 0.05
Crew V1 vs. Crew V3	WSRT, z = -2.088, p = 0.037[a]
Pilot V1 vs. Pilot V2	WSRT, z = -2.233, p = 0.026[a]
Pilot V2 vs. Pilot V3	WSRT, z = -.25, p > 0.05
Pilot V1 vs. Pilot V3	WSRT, z = -2.754, p = 0.006[a]
Copilot V1 vs. Copilot V2	WSRT, z = -2.328, p = 0.02[a]
Copilot V2 vs. Copilot V3	WSRT, z = -2.088, p = 0.813
Copilot V1 vs. Copilot V3	WSRT, z = -3.334, p = 0.001[a]

[a]Statistically significant comparisons.

3.3 Human Factors Observations

During each vignette, a human factors SME observed pilots from the battle captain station (figure 7), where observers can monitor a video feed of the aircraft in its synthetic environment, a video feed of pilot EDM activity, an over-the-shoulder video feed of the pilots, and voice communications between pilots and the battle captain. Throughout the vignettes, several key observations were made in terms of performance, air crew communication, and EDM interface activity. These observations are noted in section 3.3.1.

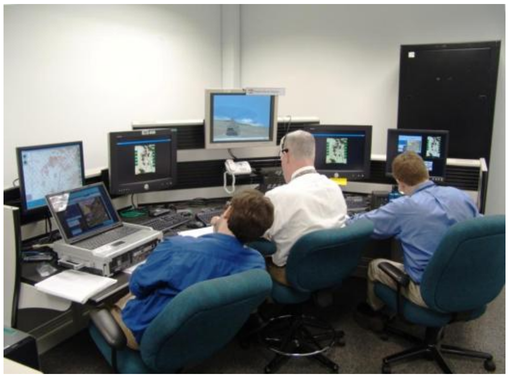


Figure 7. Battle captain station.

3.3.1 Flight Path Performance

In V1, the copilot spent a significant portion of heads-down time attempting to map out dynamic ACM events. Often they were unable to gain SA on these events quickly enough to communicate an alternate route to the pilot. Consequently, the air crew frequently flew directly through an ROZ without being aware of where exactly the danger was located until after they had passed it. This significant performance risk was mitigated by transmitting DAUs to the EDM in V2 and V3.

3.3.2 Air Crew Navigation Coordination

As previously mentioned, the copilots spent much of their time writing grid coordinates during V1. Compared to V2 and V3, there was more specific navigational instruction from copilot to pilot. For example, the copilot would instruct the pilot to bank left 10° to move around the airspace of a UAV. This type of air crew coordination occurred more frequently, introducing dynamic ACMs to the EDM and, thus, enabling the copilot to coordinate navigation information to the pilot more efficiently.

3.3.3 EDM Interface and Usage

Introducing additional symbology into the EDM display resulted in more occlusion and symbol clutter. In several instances, symbology, either from TAIS or AMPS, occluded text or was too saturated against a similarly colored background for the user to read. During operations, the user sometimes had to rotate the EDM to read text or hold the device up for the pilot to briefly view. For the current study, the EDM was not mounted to the cockpit, which influenced its usage and sharing of information. However, pilots often mount the EDM, which restricts their ability to rotate and share information displayed on the device. Typically, both pilots would have an EDM, but because of the variety of overlays and map scales, it is often easier for the copilot to show the pilot the EDM interface to gain shared SA rather than referencing information that is displayed differently on each device.

During V2, symbology from TAIS was injected into the EDM without an annunciation. In this case, symbology was often located in a position outside of the current viewing scale of the map. Thus, pilots were unaware of the new information until it came within closer range of the aircraft or the operator of the EDM happened to scale out of the map far enough to see the newly introduced ACM. In V3, this issue was mitigated by the annunciation, which enabled pilots to plan farther in advance.

In addition, when writing on the digital notepad, the copilot often had to restart writing characters because the interface did not consistently detect the user input.

3.4 Crew Open-Ended Comments

Throughout each questionnaire, pilots were asked to provide open-ended feedback to various questions regarding workload, SA, and the EDM. The most consistently expressed issues are discussed in the following paragraphs. The raw data is presented in appendices E and F.

3.4.1 Workload Open-Ended Comments

Several primary themes emerged from the open-ended workload comments. First, there was a lack of EDM training. In addition, workload was significantly increased when the EDM data was not syncronizing properly. These data suggest that workload will increase to unmanageable levels in the event of EDM failure.

3.4.2 SA Open-Ended Comments

Open-ended SA comments revealed three issues. First, during technical difficulties in which data did not properly sync with the EDM, pilots consistently reported low SA. These responses suggest pilot reliance on EDM technology and its overall effectiveness in providing SA. Second, several pilots pointed out the difficulty in predicting UAV headings. This information is particularly important for alternate course of action route planning. Third, as mentioned previously, text was difficult for pilots to read and ROZs were not transparent enough to see any other information within the ROZ symbology.

3.4.3 EDM Open-Ended Comments

The overall EDM responses point to the benefits and issues outlined in table 6.

Table 6. EDM responses.

Unfavorable Responses	Favorable Responses
The notepad was hard to read and write on.	The digital map and route overlays were beneficial.
The device was too hot to keep strapped on their leg for extended periods.	The dynamic airspace changes provided excellent SA.
ACMs not transparent enough.	The moving map capability was helpful.
Lack of customization.	The “next ACP information” function helped to inform navigation decisions.
Inability to pan maps.	The “look forward,” “look backward,” and “direct too” map navigation functions worked well.
Font size was not big enough.	Enabled us to maintain airspace surveillance.
Text was sometimes upside down.	ROZs provided excellent navigation information.
Unable to predict UAV heading.	—
Symbols often blended into the map.	—
Maps were slow to load.	—
Lack of EDM training.	—

Overall, these responses support the following notions. First, the EDM is an excellent source of SA for the pilots, particularly when dynamic ACMs are automatically pushed to the device. Second, there are several graphical user interface issues on the EDM that need to be addressed, particularly with the addition of more symbology to the interface. Font size, text orientation, and symbol clutter (ACM transparency) are all issues that will require further development and testing to properly integrate the EDM into the cockpit.

4. Conclusions

4.1 Crew Workload

The overall trend of the BWRS data indicates a continuous reduction of workload from V1 to V3 for both pilot and copilot. However, the magnitude of the reduction was the largest for the copilot and from V1 to V2. There were further reductions in workload from V2 to V3 but they were not as pronounced as the first comparison. A similar trend was reflected when comparing the effects of DAUs on the reduction of pilot workload. While the copilot experienced the greater effect, the pilot was affected, demonstrating that the information that was initially presented only to the copilot had a measurable effect on the other crew member.

Pilots reported that they typically experienced tolerable workloads when performing all missions. However, all peak workload scores were reported during V1, which represented the current capability, in which the copilot was required to mentally transform lattitude/longitude data to gain SA about DAUs. By comparison, the workload scores obtained during V2 and V3 indicate a substantial reduction in crew workload attributable to integrating dynamic airspace symbology from TAIS into the cockpit.

The highest average BWRS score was a 6 on ATM task 1026 (maintain airspace surveillance), and was produced by copilots indicating that “the level of effort allowed for little attention to additional tasks.” The consequence of this unmanageable level of workload is that the copilot cannot adequately inform the pilot of flight route alterations. On several occasions, the pilot flew directly through several ROZs without any warning of the potential danger. This is a serious risk that was mitigated by the support of dynamic information being automatically transmitted into the cockpit.

The remaining three of the highest BWRS scores were all in reference to EDM usage, which can be attributed to pilot familiarity with the EDM and symbol clutter issues (including font size and text orientation). Navigating the EDM and changing the EDM map scales initially received higher than average scores but deflated across vignettes. This is most likely due to increased familiarity with the device because the introduction of dynamic TAIS symbology in V2 and V3 had no effect on the mechanics of operating the EDM. However, BWRS scores for reading symbology on the EDM remained higher than average across all vignettes. This is due to the increase in symbol clutter from the addition of TAIS symbology. The solution to this problem is complex and will require further study to optimize the presentation of numerous and complex symbology on a dynamic background.

4.2 Visual Workload

Visual workload, i.e., eye and head tracker data, indicated unacceptable visual demands on the copilot during V1. Throughout V1, 78.73% of the copilots' time was spent gazing at the notepad and EDM, while only 5.34% of their time was spent maintaining airspace surveillance. This left the task of airspace surveillance almost solely up to the pilot, which means that every time the pilot looked down (typically 15% to 39% of the total flight time, according to Havir et al., 2006) there is a high probability that *neither crew member was looking outside the window*.

During V2 and V3, visual workload was reduced significantly compared to V1. The OTW viewing times increased substantially from 5.34% in V1 to 24.29% in V2 and to 27.68% in V3. This indicates that there was a considerable "release" of visual capture with the introduction of dynamic ACM information. Results obtained in V2 and V3 were consistent with copilot OTW viewing times reported during other simulation tests (Havir et al., 2006). Although a statistical analysis was not conducted on this data because of a low sample size, visual workload appears to have remained constant across V2 and V3, indicating that the increase in SA and slight reduction in BWRS scores from V2 to V3 occurred with no additional cost of visual workload.

4.3 Crew Situational Awareness

Overall, the SART and battlefield elements SA data indicate that SA was significantly increased by the integration of dynamic ACM events into the cockpit. These results can be interpreted based on Endsley's (1995b) three stages of SA (perception, comprehension, and projection).

4.3.1 Level 1 Situational Awareness (Perception)

During V1, copilots failed to consistently gain timely perception of dynamic ACM events. Events in which flight routes were successfully altered based on new information were too taxing for the copilot to maintain airspace surveillance. Thus, the cost incurred by the copilot, an inconsistent gain in basic perceptual information about important airspace events, was unacceptably high. This decreases performance and indicates that critical incidences (incidences of fratricide and controlled flight into terrain [CFIT]) will become more probable as the airspace becomes more congested. Comprehension and prediction of airspace elements was minimal in V1.

4.3.2 Level 2 and 3 Situational Awareness (Comprehension and Prediction)

During V2, copilots were capable of gaining perceptual SA in an efficient manner. Consequently, because of the nature in which the information was presented (spatial information presented visually as opposed to verbally), they were able to comprehend multiple sources of information and gain an overall mission picture that allowed pilots to predict and then alter their flight path. Moreover, crew access to dynamic airspace information related to environmental changes and the commander's response to those changes (reflective of intent) provide the building blocks for *situational understanding.* Without a near-real-time airspace picture, pilots will not be able to gain situational understanding while operating in a dynamic environment. Essentially, the same effect occurred during V3 but the addition of an annunciation provided more consistent and timely perception of airspace elements. The increased consistency of perceiving the newly introduced elements amplified comprehension of dynamic airspace events. That consistency, combined with an increase in timeliness, supported the predictability of airspace events.

4.4 Electronic Data Management Interface

As an interface for displaying airspace symbology, the EDM was widely accepted by the user group, particularly for its basic map overlays, route display, and general navigation support. However, several issues must be resolved that relate to alterations to the device with the addition of DAUs, for example, how dynamic airspace symbology is presented (font size, orientation, and clutter issues) and, more generally, EDM usage issues unrelated to the introduction of dynamic airspace symbology. Pilots also reported that the device became too hot to strap onto their legs, a pan feature should be added, the notepad was inadequate, and the device was too slow when updating maps and symbology. Further software development should mitigate the interface issues, while mounting the EDM to the cockpit would alleviate the heat issue.

4.4.1 Dynamic Airspace Integration Issues: Symbol Clutter/Saturation and Transparency

The primary concerns of introducing dynamic airspace symbology into the EDM are symbol clutter and transparency. Currently, if symbols overlap each other, at least one will be occluded; often both become illegible. To mitigate this issue, the EDM user should be able to select a cluster of symbols and distribute them so that the user can view each symbol related to the same overlapping area and select it to gain further information, such as altitudes and expiration. ROZ transparency also needs to be altered so that text or symbology within the ROZ is still detectable. In addition, in some instances, symbols were masked because of the similarity of the symbol hue and map overlay hue. A hue-correlation detection algorithm could be introduced to correlate symbol hue with the currently selected map overlay and alter the symbol hue to a color that is easily viewed in that particular map overlay. This is a particularly complex problem requiring further development and testing.

4.5 Summary of Conclusions

Rotary-wing assets with analog cockpits currently rely on radio communications for dynamic airspace information. As such, the current method of transmitting information into the cockpit requires an increase in overall crew workload (particularly for the copilot), creates extensive visual demands that divert the copilot's visual attention away from OTW, and hinders SA and the development of situational understanding. The consequences of these measures indicate that in the increasingly congested airspace, a higher probability of fratricide and CFIT incidence will likely occur unless a mitigation strategy is implemented to augment the capabilities of the system to match the requirements of the current and future airspace environment. To meet these needs, the current test simulated the integration of near-real-time TAIS symbology into the cockpit and measured its effects. Overall, copilots experienced a reduction in workload because of the efficiency in which dynamic information was presented, a decrease in visual workload because visual capture was released for OTW viewing, and increased SA because of the mode in which information was more efficiently presented, i.e., spatial information in a spatial display as opposed to spatial information transmitted verbally.

5. Point of Contact

Questions regarding this report should be directed to: Mr. M. Sage Jessee, ARL-HRED, AMCOM Field Element, at DSN 788-8830 (michael.sage.jessee@us.army.mil), or Dr. Anthony Morris at DSN 788-9556 (tony.w.morris@us.army.mil).

6. References

Endsley, M. R. Design and Evaluation for Situation Awareness Enhancement. In *Proceedings of the Human Factors Society 32nd Annual Meeting*; Human Factors Society: Santa Monica, CA, 1988; pp 97–101.

Endsley, M. R. Toward a theory of situation awareness in dynamic systems. *Human Factors* **1995b**, *37* (1), 32–64.

Endsley, M. R. Theoretical Underpinnings of Situation Awareness: A Critical Review. In *Situation Awareness Analysis and Measurement*; Endsley, M. R. and Garland, D. J., Eds.; Lawrence Erlbaum Associates: Mahwah, NJ, 2000; pp 3–32.

Havir, T. J.; Durbin, D. B.; Frederick L. J.; Hicks, J. S. *Human Factors Assessment of the UH-60M Crew Station During the Limited User Test*; ARL-TR-3730; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

O'Brien, T. G.; Charlton, S. G. *Handbook of Human Factors Testing and Evaluation*; Lawrence Erlbaum Associates: Mahwah, NJ, 1996.

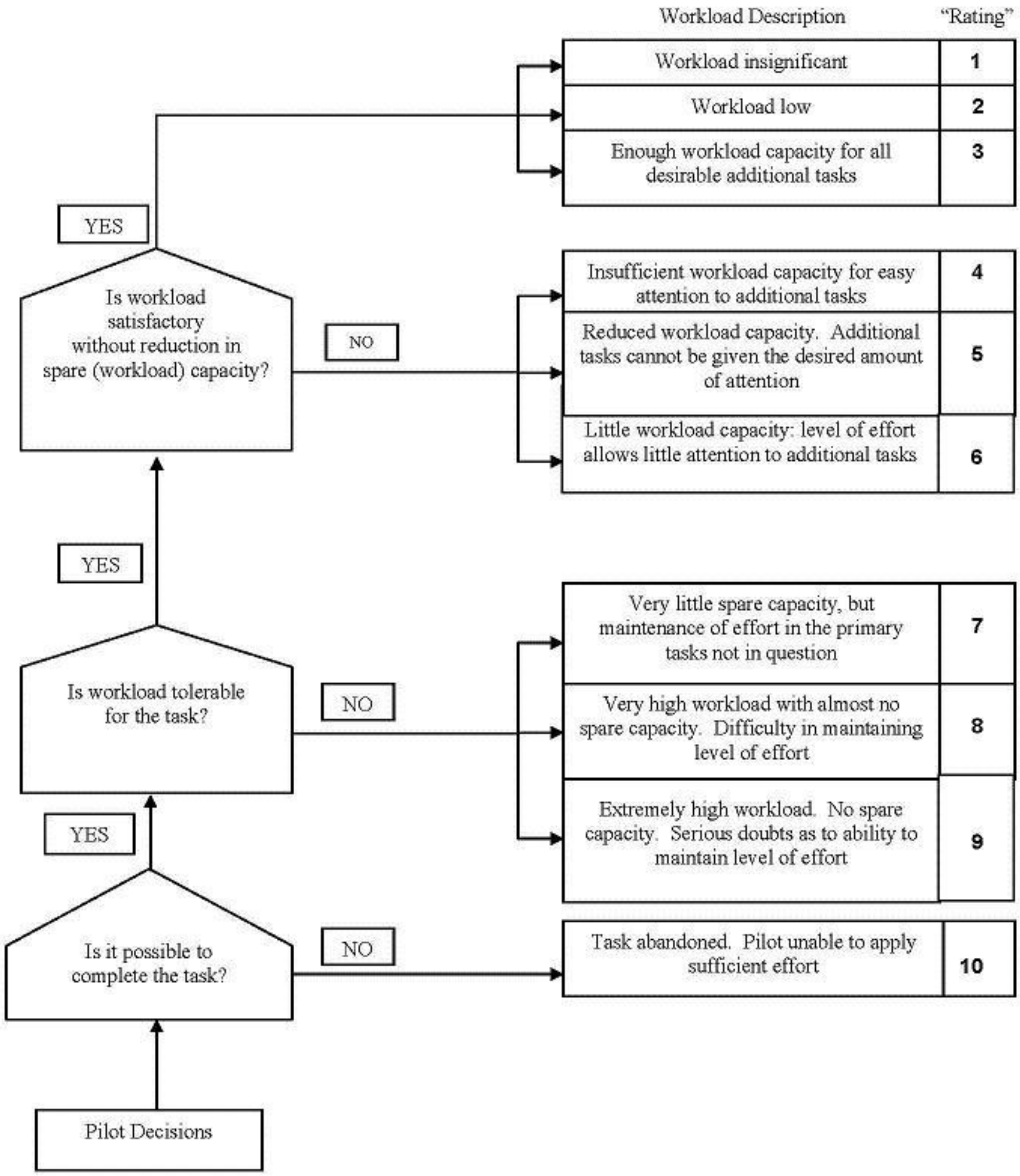
Roscoe, A. H.; Ellis, G. A. *A Subjective Rating Scale for Assessing Pilot Workload in Flight*; TR90019; Royal Aeronautical Establishment: Farnborough, UK, 1990.

Taylor, R. M. Situation Awareness Rating Technique (SART): The Development of a Tool for Aircrew Systems Design. In *Situational Awareness in Aerospace Operations* (AGARD-CP-478); NATO-AGARD: Neuilly-Sur-Seine, France, 1990; pp 3/1–3/17.

Young, M. S.; Stanton, N. A. Mental Workload: Theory, Measurement, and Application. In *International Encyclopedia of Ergonomics and Human Factors: Volume 1*; Karwowski, W., Ed.; Taylor & Francis: London, 2001; pp 507–509.

Appendix A. Bedford Workload Decision Tree

This appendix appears in its original form, without editorial change.


Workload Description
"Rating"
Workload insignificant
1
Workload low
2
Enough workload capacity for all desirable additional tasks
3
YES
Is workload satisfactory without reduction in spare (workload) capacity?
NO
Insufficient workload capacity for easy attention to additional tasks
4
Reduced workload capacity. Additional tasks cannot be given the desired amount of attention
5
Little workload capacity: level of effort allows little attention to additional tasks
6
YES
Very little spare capacity, but maintenance of effort in the primary tasks not in question
7
Is workload tolerable for the task?
NO
Very high workload with almost no spare capacity. Difficulty in maintaining level of effort
8
YES
Extremely high workload. No spare capacity. Serious doubts as to ability to maintain level of effort
9
Is it possible to complete the task?
NO
Task abandoned. Pilot unable to apply sufficient effort
10
Pilot Decisions

Appendix B. Situational Awareness Rating Technique

This appendix appears in its original form, without editorial change.

SA1. Situation Awareness is defined as "timely knowledge of what is happening as you perform your tasks during the mission."

Situation Awareness Rating Technique (SART)	
DEMAND	
Instability of Situation	**Likeliness of situation to change suddenly.**
Variability of Situation	**Number of variables which require your attention**
Complexity of Situation	**Degree of complication (number of closely connected parts) of the situation**
SUPPLY	
Arousal	**Degree to which you are ready for activity; ability to anticipate and keep up with the flow of events**
Spare Mental Capacity	**Amount of mental ability available to apply to new tasks**
Concentration	**Degree to which your thoughts are brought to bear on the situation; degree to which you focused on important elements and events**
Division of Attention	**Ability to divide your attention among several key issues during the mission; ability to concern yourself with many aspects of current and future events simultaneously**
UNDERSTANDING	
Information Quantity	**Amount of knowledge received and understood**
Information Quality	**Degree of goodness or value of knowledge communicated**
Familiarity	**Degree of acquaintance with the situation**

Rate the level of each component of situation awareness that you had. Circle the appropriate number for each component of situation awareness (e.g., complexity of situation).

DEMAND:

Instability of situation: (low = stability)	**Low 1-----2-----3-----4-----5-----6-----7 High**
Variability of situation: (low = few variables)	**Low 1-----2-----3-----4-----5-----6-----7 High**
Complexity of situation: (low = less complexity)	**Low 1-----2-----3-----4-----5-----6-----7 High**

SUPPLY:

Arousal: (low = not aroused)	**Low 1-----2-----3-----4-----5-----6-----7 High**
Spare mental capacity: (low = small amount)	**Low 1-----2-----3-----4-----5-----6-----7 High**
Concentration: (low = unfocused on situation)	**Low 1-----2-----3-----4-----5-----6-----7 High**
Division of attention: (low = no multitasking)	**Low 1-----2-----3-----4-----5-----6-----7 High**

UNDERSTANDING:

Information quantity: (low = little info)	**Low 1-----2-----3-----4-----5-----6-----7 High**
Information quality: (low = less value)	**Low 1-----2-----3-----4-----5-----6-----7 High**
Familiarity: (low = novel)	**Low 1-----2-----3-----4-----5-----6-----7 High**

Appendix C. Copilot Open-Ended Survey Responses

This appendix appears in its original form, without editorial change.

SA2. Rate the level of situational awareness you had for each of the battlefield elements during the mission by placing and X in the appropriate column for each battlefield element.

Battlefield Elements	Very High Level of Situation Awareness	Fairly High Level of Situation Awareness	Intermediate Level of Situation Awareness	Fairly Low Level of Situation Awareness	Very Low Level of Situation Awareness
Location of Friendly Units					
Location of My Aircraft During Mission					
Location of Other Aircraft Related to the Mission					
Location of Cultural Features e.g., Bridges					
Route Information (ACPs, BPs, EAs, RPs)					

Describe any instances when you feel you had low situational awareness during the mission:

____

____

____

Appendix D. Electronic Data Manager (EDM) Questionnaire

This appendix appears in its original form, without editorial change.

Please answer the below questions honestly based on your experience conducting these mission excursions.

1. Did you have adequate information to aid the pilot in navigation tasks?

If yes, please explain

If no, please explain

2. How did the EDM support your need for navigational information?

3. Explain how the EDM visual information clarified verbal navigation between copilot and pilot?

4. Explain how you used the change of scale EDM map feature?

5. Explain how radio transmitted information helped you in your mission (Irrelevant for Excursion 2)

6. How quickly did you observe EDM dynamic visual notifications (Irrelevant for Excursion 1)?

____

____

7. Which ACM icons communicated the MOST readily available navigation information?

____

____

8. Which ACM icons communicated the LEAST readily available navigation information?

____

____

9. Please provide any other comments regarding how the EDM supported your mission?

____

____

10. Please name 3 likes and 3 dislikes regarding your experience with the EDM?

3 Ups

____

____

____

3 Downs

____

____

____

INTENTIONALLY LEFT BLANK.

Appendix E. Copilot Open-Ended Survey Responses

This appendix appears in its original form, without editorial change.

VIGNETTE 1

Workload Comments

1. If you gave a workload rating of '6' or higher for any task, explain why the workload was high for that task:
   - EDM was acting up, GPS data kept going out
   - I was unable to plot SA on the map. There was a lack of EDM training. Also, TOH given in Lat/Long, Grid in MGRS not able to compare grid quick enough

2. In the mission you just flew, list any flight and/or mission tasks that you had to ask your crewmember to accomplish because you workload was too high:
   - Gave him the route card to focus on restarting the EDM or sinking the data

Situational Awareness Comments

1. Describe any instances when you feel you had low situational awareness during the mission:
   - There were no ROZs displayed and it is hard to interpret the grid on a moving map
   - The radio uploader had limited information associated with the effective ROZ and I was unable to plot it on the EDM

EDM Related Comments

1. Did you have adequate information to aid the pilot in navigation tasks?

Yes, please explain…
   - Route overlays are great
   - Route information was detailed enough to stay on schedule to get to LZs

No, please explain…
   - *No Responses*

2. How did the EDM support your need for navigational information?
   - Training target graphics (TTG) needs to be more accurate and stable
   - Route color and symbols were good. EDM was too slow to upload

3. Explain how the EDM visual information clarified verbal navigation between copilot and pilot?
   - It is better when you know where to go and where we are. It then becomes easier to correct the navigation
   - Provided guidance on the course to the LZ and along the route

4. Explain how you used the change of scale EDM map feature?
   - To maintain SA and look ahead, or look for more detail
   - I didn't know how to use the change of scale EDM map feature. It really needs a tactical map.

5. Explain how radio transmitted information helped you in your mission?
   - Gave me some info but it added to workload by requiring transformation to moving map
   - It told me of hazards, but not to the detail that was needed

6. Which ACM icons communicated the MOST readily available navigation information?

- Some of the preloads were good
- Control Zone
- Couldn't tell if RZ 3A was blue?

7. Which ACM icons communicated the LEAST readily available navigation information?

- BFT icons

8. Please provide any other comments regarding how the EDM supported your mission?

- Good to have a pigmap
- Navigation

3 Ups:

- Good maps
- Graphic capability
- Messages
- Route
- ACPs
- Maps

3 Downs:

- No top level data
- Lack of customization
- Too much heat
- Control Zones were not transparent enough
- Updates were too slow
- Not enough meta data

11. In what ways did the digital note pad on the EDM assist or hinder you?

- It is a little hard to read and write on
- Didn't use it

12. Compared to a paper and pencil pad, describe the benefits and shortcomings of the EDM note pad.

- Didn't use it

13. What additional map navigation features beyond "look ahead" "look back" and "zoom" would you add to the EDM?

- Slew – drag and drop
- Add an SA look up feature to publish a grid to see its location to the map/route

14. How did the map navigation features support your decisions and actions regarding the dynamic ACM symbols?

- It helped to keep us out of the ACM

VIGNETTE 2 COMMENTS

Workload Comments

1. If you gave a workload rating of '6' or higher for any task, explain why the workload was high for that task:
   - *No responses*

2. In the mission you just flew, list any flight and/or mission tasks that you had to ask your crewmember to accomplish because you workload was too high:
   - *No responses*

Situational Awareness Comments

1. Describe any instances when you feel you had low situational awareness during the mission:
   - During the mission the EDM lost position info causing the crew to revert to pilotege/dead reckoning for approx 1.5 minutes
   - It was difficult to anticipate the direction of UAV travel
   - Low SA when the EDM was updating slowly
   - More training on symbols and EDM would have generally increased SA

EDM Related Comments

1. Did you have adequate information to aid the pilot in navigation tasks?

Yes, please explain…
   - Yes, all navigation data provided allowed for successful mission accomplishment
   - Route information and ACMs provided enough info to perform mission
   - All information was adequate

No, please explain…
   - *No Responses*

2. How did the EDM support your need for navigational information?
   - Provided necessary data to perform electronically aided navigation
   - Provided route data
   - Provided SA

3. Explain how the EDM visual information clarified verbal navigation between copilot and pilot?
   - Able to share visual data to formulate alternate COAs if required
   - Able to show ACMs to verify any decision to alter planned rout

4. Explain how you used the change of scale EDM map feature?
   - Carefully, it didn't want to cooperate

5. How quickly did you observe EDM dynamic visual notifications?
   - Almost immediately
   - I believe, fairly quickly after they were displayed
   - Possibly need an audio alert

6. Which ACM icons communicated the MOST readily available navigation information?

- ROZ, corridors, ect…
- ROZ, ACM used to alter routes as necessary
- Control Zones

7. Which ACM icons communicated the LEAST readily available navigation information?

- UAV symbols too slow on update
- Small UAV icons moved too slow/updated too slow to reposition aircraft if necessary
- I couldn't tell the direction of travel of the UAVs

8. Please provide any other comments regarding how the EDM supported your mission?

- During change of mission, I was able to move forward to verify ACP location to navigate direct to
- Good for navigation

9. Please name 3 likes and 3 dislikes regarding your experience with the EDM?
3 Ups:

- ACP selection for direct to navigation
- Dynamic ACMs displayed
- Route info
- Overall mission picture
- Flight route
- Color of ROZ was good

3 Downs:

- No pan feature
- Lack of other map scales (simulation issue)
- Too much heat generated on the leg
- Too much heat
- Inability to pan map
- Font size on some of the text is too small (this was inconsistent throughout the mission)
- Text was upside down
- UAV didn't indicate direction of flight
- Symbols blended into map

10. In what ways did the digital note pad on the EDM assist or hinder you?

- Unreadable
- Not legible and didn't work properly

11. Compared to a paper and pencil pad, describe the benefits and shortcomings of the EDM note pad.

- Did not use
- Did not use
- No benefit and not legible

12. What additional map navigation features beyond “look ahead” “look back” and “zoom” would you add to the EDM?

- Pan/Direct to feature
- Next ACP information
- Pan (grab and drag map, just like google earth)

13. How did the map navigation features support your decisions and actions regarding the dynamic ACM symbols?

- Allowed me to adjust routes as required to complete the mission
- Provided good SA for rerouting missions
- Allowed me to look ahead to see if any ACMs would interfere with the route of the flight

VIGNETTE 3 COMMENTS

Workload Comments

1. If you gave a workload rating of ‘6’ or higher for any task, explain why the workload was high for that task:

- *No Responses*

2. In the mission you just flew, list any flight and/or mission tasks that you had to ask your crewmember to accomplish because you workload was too high:

- GPS lost data, pilot had to take on airspace overview until EDM was synced

Situational Awareness Comments

1. Describe any instances when you feel you had low situational awareness during the mission:

- Friendly forces jumped around a bit on the EDM
- Transparency and some lettering were hard to see or see through. Need meta drop down boxes

EDM Related Comments

1. Did you have adequate information to aid the pilot in navigation tasks?
Yes, please explain…

- The moving map was good
- Dynamic changes provided the needed SA
- Yes, route info and appearance of ACMs made adjustments to routes easy

No, please explain…

- I could use more top level data. For example TTG and digital target graphics (DTG)

2. How did the EDM support your need for navigational information?

- Could be even better
- GPS was lost for 5 minutes, which reduced SA
- Yes, it provided current position data and route info

3. Explain how the EDM visual information clarified verbal navigation between copilot and pilot?

- It is good, but there could be more
- EDM was easy to read from both seats, with the exception of text. Copilot had to read text to pilot
- Used EDM to show pilot on controls the situation periodically throughout the flight

4. Explain how you used the change of scale EDM map feature?

- In order to look ahead
- Supported different mission sets
- Did not use

5. Explain how radio transmitted information helped you in your mission.

- Too much talking
- It helped with SA for ACMs
- Confirmed that ACM had appeared on EDM

6. How quickly did you observe EDM dynamic visual notifications?

- Very quickly
- Quickly enough
- Almost immediately

7. Which ACM icons communicated the MOST readily available navigation information?

- ROZ and ACM for RTE
- Routes and ROZs
- ROZs

8. Which ACM icons communicated the LEAST readily available navigation information?

- BFT, due to lag
- AH-64s and UAVs
- UAV symbols

9. Please provide any other comments regarding how the EDM supported your mission?

- It provided me what I need to complete the mission, but still could be streamlined a bit more
- Position data of the UAVs were good

10. Please name 3 likes and 3 dislikes regarding your experience with the EDM?
3 Ups:

- Routes and ACPS
- Look forward/look back feature
- Direct to feature
- Navigation data

3 Downs:

- Its small
- It's too hot
- Direction of travel for the UAVs was unclear
- Text format
- Lack of map scales
- Ease of use of zoom feature
- Slow to load map data

11. In what ways did the digital note pad on the EDM assist or hinder you?

- It was worthless
- Did not use

12. Compared to a paper and pencil pad, describe the benefits and shortcomings of the EDM note pad.

- No benefits
- Not readable

13. What additional map navigation features beyond "look ahead" "look back" and "zoom" would you add to the EDM?

- Slew (drag with cursor)
- Drop down boxes
- Better touch response and highlight the touched/active box
- Pan feature and the ability to mark certain points

14. How did the map navigation features support your decisions and actions regarding the dynamic ACM symbols?

- Allowed navigation around the ACMs
- Allowed me to navigate around ACMs

Appendix F. Pilot Open-Ended Survey Responses

This appendix appears in its original form, without editorial change.

VIGNETTE 1

Workload Comments

1. If you gave a workload rating of '6' or higher for any task, explain why the workload was high for that task:

- *No Responses*

2. In the mission you just flew, list any flight and/or mission tasks that you had to ask your crewmember to accomplish because you workload was too high:

- *No Responses*

Situational Awareness Comments

1. Describe any instances when you feel you had low situational awareness during the mission:

- Not able to quickly plot received tactical SA on EDM due to training on equipment.
- When the GPS data was lagging

EDM Related Comments

1. Did the copilot have adequate information to aid navigation?

Yes, please explain

- Route on EDM was sufficient to navigate aircraft

No, please explain

- No, with the GPS data out, we got off course

2. How did the EDM support the copilot's need for navigational information, from your perspective?

- What was loaded by AMPS was sufficient until new ACMs were received. Any new information would have to be manually looked up to confirm if it interfered with the route of flight or mission
- Didn't give good SA. Didn't know where some of the SA given was located, and couldn't plot it.

3. Explain how radio transmitted information helped you in your mission

- Gave us a heads up to the possibility of ACMs that might affect the mission
- Let us know to look, but we didn't know where to look

4. Please provide any other comments regarding how the EDM supported your mission?

- We were able to use it for navigation only

5. Please name 3 likes and 3 dislikes regarding your experience with the EDM?

3 Ups:

- Moving maps
- Route information
- Navigation information

3 Downs:

- Lack of EDM training

VIGNETTE 2

Workload Comments

1. If you gave a workload rating of '6' or higher for any task, explain why the workload was high for that task:

- *No Responses*

2. In the mission you just flew, list any flight and/or mission tasks that you had to ask your crewmember to accomplish because you workload was too high:

- *No Responses*

Situational Awareness Comments

1. Describe any instances when you feel you had low situational awareness during the mission:

- None as pilot on controls
- During loss of GPS data, all SA data became stale

EDM Related Comments

1. Did the copilot have adequate information to aid navigation?

Yes, please explain

- Route information provided sufficient navigation guidance to perform mission
- Yes, a mix of EDM data and dead reckoning
- Yes, same as before

No, please explain

- No, with the GPS data out, we got off course

2. How did the EDM support the copilot's need for navigational information, from your perspective?

- Provided basic navigation information
- He was able to cross reference the EDM and track data
- Same as before

3. Please provide any other comments regarding how the EDM supported your mission?

- Having ACMs appear allowed to the crew to develop alternate COAs during the mission
- Good SA to the flying pilot

4. Please name 3 likes and 3 dislikes regarding your experience with the EDM?

3 Ups:

- Navigation data provided
- ACM updates were great
- Look ahead feature

- It aided navigation
- Great visual cueing to flight hazards

3 Downs:

- Notepad was unreadable
- Maps were slow to load
- Updates were slow to load
- Need to expand look ahead functions
- Increase the processing speed

VIGNETTE 3

Workload Comments

1. If you gave a workload rating of '6' or higher for any task, explain why the workload was high for that task:
    - *No Responses*

2. In the mission you just flew, list any flight and/or mission tasks that you had to ask your crewmember to accomplish because you workload was too high:
    - *No Responses*

Situational Awareness Comments

1. Describe any instances when you feel you had low situational awareness during the mission:
    - Any time the GPS sync was lost, specifically when nearing a turn or ROZ.

EDM Related Comments

1. Did the copilot have adequate information to aid navigation?

Yes, please explain

- Yes, the information presented was adequate. When able to view the course data it allowed for timely course corrections
- Navigation data provided guidance for aircraft
- All SA was adequate

No, please explain

- *No responses*

2. How did the EDM support the copilot's need for navigational information, from your perspective?
    - Visual cueing and guidance. Also, graphical representations of hazards
    - Provided all necessary information to conduct mission
    - SA allowed us to reroute when needed

3. Explain how radio transmitted information helped you in your mission.
    - It brought attention to the hazard. It was an initial "yeah you, be ready for map data update"

- Gave heads up to mission changes that might affect route of flight

4. Please provide any other comments regarding how the EDM supported your mission?
    - Excellent mission aid, but needs a little more development
    - Provided SA to make decisions that affected mission
    - Allowed us to maintain airspace surveillance

5. Please name 3 likes and 3 dislikes regarding your experience with the EDM?

3 Ups:

- Route data
- Flight hazard data
- Real time updates
- Route information
- Look ahead/behind/zoom function

3 Downs:

- GPS sync loss
- Text data positioning and size
- ROZ box translucence was not good
- Lack of map scales available
- All text was not oriented in relation to route of flight
- Fonts too small for cross cockpit viewing

NO. OF COPIES	ORGANIZATION
1 (PDF)	DEFENSE TECHNICAL INFORMATION CTR DTIC OCA 8725 JOHN J KINGMAN RD STE 0944 FORT BELVOIR VA 22060-6218
1 (HC)	DIRECTOR US ARMY RESEARCH LAB IMAL HRA 2800 POWDER MILL RD ADELPHI MD 20783-1197
1 (PDF)	DIRECTOR US ARMY RESEARCH LAB RDRL CIO LL 2800 POWDER MILL RD ADELPHI MD 20783-1197
1 (PDF)	GOVT PRINTG OFC A MALHOTRA 732 N CAPITOL ST NW WASHINGTON DC 20401
1 (PDF)	ARMY RSCH LABORATORY – HRED RDRL HRM C A DAVISON 320 MANSCEN LOOP STE 115 FORT LEONARD WOOD MO 65473
1 (PDF)	ARMY RSCH LABORATORY – HRED RDRL HRM D T DAVIS BLDG 5400 RM C242 REDSTONE ARSENAL AL 35898-7290
1 (HC)	ARMY RSCH LABORATORY – HRED RDRL HRS EA DR V J RICE BLDG 4011 RM 217 1750 GREELEY RD FORT SAM HOUSTON TX 78234-5002
1 (PDF)	ARMY RSCH LABORATORY – HRED RDRL HRM DG J RUBINSTEIN BLDG 333 PICATINNY ARSENAL NJ 07806-5000
1 (PDF)	ARMY RSCH LABORATORY – HRED ARMC FIELD ELEMENT RDRL HRM CH C BURNS THIRD AVE BLDG 1467B RM 336 FORT KNOX KY 40121

NO. OF COPIES	ORGANIZATION
1 (PDF)	ARMY RSCH LABORATORY – HRED AWC FIELD ELEMENT RDRL HRM DJ D DURBIN BLDG 4506 (DCD) RM 107 FORT RUCKER AL 36362-5000
1 (PDF)	ARMY RSCH LABORATORY – HRED RDRL HRM CK J REINHART 10125 KINGMAN RD BLDG 317 FORT BELVOIR VA 22060-5828
1 (PDF)	ARMY RSCH LABORATORY – HRED RDRL HRM AY M BARNES 2520 HEALY AVE STE 1172 BLDG 51005 FORT HUACHUCA AZ 85613-7069
1 (PDF)	ARMY RSCH LABORATORY – HRED RDRL HRM AP D UNGVARSKY POPE HALL BLDG 470 BCBL 806 HARRISON DR FORT LEAVENWORTH KS 66027-2302
1 (PDF)	ARMY RSCH LABORATORY – HRED RDRL HRM AT J CHEN 12423 RESEARCH PKWY ORLANDO FL 32826-3276
1 (PDF)	ARMY RSCH LABORATORY – HRED RDRL HRM AT C KORTENHAUS 12350 RESEARCH PKWY ORLANDO FL 32826-3276
1 (HC)	ARMY RSCH LABORATORY – HRED RDRL HRM CU B LUTAS-SPENCER 6501 E 11 MILE RD MS 284 BLDG 200A 2ND FL RM 2104 WARREN MI 48397-5000
1 (PDF)	ARMY RSCH LABORATORY – HRED FIRES CTR OF EXCELLENCE FIELD ELEMENT RDRL HRM AF C HERNANDEZ 3040 NW AUSTIN RD RM 221 FORT SILL OK 73503-9043
1 (PDF)	ARMY RSCH LABORATORY – HRED RDRL HRM AV W CULBERTSON 91012 STATION AVE FORT HOOD TX 76544-5073

NO. OF
COPIES ORGANIZATION

1 (HC) ARMY RSCH LABORATORY – HRED
HUMAN RSRCH AND ENGRNG
DIRCTRT MCOE FIELD ELEMENT
RDRL HRM DW C CARSTENS
6450 WAY ST
BLDG 2839 RM 310
FORT BENNING GA 31905-5400

1 (PDF) ARMY RSCH LABORATORY – HRED
RDRL HRM A MARES
1733 PLEASONTON ROAD, BOX 3
FORT BLISS TX 79916-6816

8 (5 PDF, 3 HC) ARMY RSCH LABORATORY – HRED
SIMULATION & TRAINING
TECHNOLOGY CENTER
RDRL HRT COL M CLARKE (HC)
RDRL HRT I MARTINEZ (PDF)
RDRL HRT R SOTTILARE (HC)
RDRL HRT B N FINKELSTEIN (HC)
RDRL HRT G A RODRIGUEZ (PDF)
RDRL HRT I J HART (PDF)
RDRL HRT M C METEVIER (PDF)
RDRL HRT S B PETTIT (PDF)
12423 RESEARCH PARKWAY
ORLANDO FL 32826

1 (PDF) ARMY RSCH LABORATORY – HRED
(PDF) HQ USASOC
RDRL HRM CN R SPENCER
BLDG E2929 DESERT STORM DRIVE
FORT BRAGG NC 28310

1 (PDF) ARMY G1
DAPE MR B KNAPP
300 ARMY PENTAGON RM 2C489
WASHINGTON DC 20310-0300

ABERDEEN PROVING GROUND

12 (11 PDF, 1 HC) DIR USARL
RDRL HR
L ALLENDER (PDF)
P FRANASZCZUK (PDF)
C COSENZO (PDF)
RDRL HRM
P SAVAGE-KNEPSHIELD (PDF)
RDRL HRM
C PAULILLO (HC)
RDRL HRM B
C SAMMS (PDF)
RDRL HRM C
L GARRETT (PDF)

NO. OF
COPIES ORGANIZATION

RDRL HRS
J LOCKETT (PDF)
RDRL HRS B
M LAFIANDRA (PDF)
RDRL HRS C
K MCDOWELL (PDF)
RDRL HRS D
B AMREIN (PDF)
RDRL HRS E
D HEADLEY (PDF)

INTENTIONALLY LEFT BLANK.